MONTHLY WEATHER REVIEW

CHARLES F. BROOKS, Editor.

VOL. 47, No. 10.
W. B. No. 696.

OCTOBER, 1919.

CLOSED DECEMBER 3, 1919
ISSUED JANUARY 10, 1920

THE EVOLUTION OF THE SNOW CRYSTAL.[1]

JOHN C. SHEDD, Professor of Physics, Occidental College.

The snow crystal, solidifying as it does from the vapor of the atmosphere, is formed under circumstances exceptionally favorable to freedom of movement of the molecules. The passage of the material of which the crystal is made direct from the vaporous to the solid state, without passing through the liquid stage, is a circumstance not generally met with. These facts, no doubt, account for the great variety of crystal form observed, a variety not approached by any other mineral. It is, however, not so clear as to what determines the formation of one or other of the various types.

Of the observers, both in Europe and America, who have devoted their attention to the study of snow crystals Mr. W. A. Bentley, of Jericho, Vt., has undoubtedly gathered the most extensive and valuable body of data in existence. During the past 37 years he has each winter secured microphotographs of snow forms, until his collection now comprises over 3,000 negatives. In the U. S. MONTHLY WEATHER REVIEW for 1902 he gives an interesting summary of his work up to that date, together with reproductions of 255 microphotographs.

In 1899, while at the University of Wisconsin, I had the opportunity of seeing a large number of lantern slides made by Mr. Bentley. In 1900, on removal to Colorado College, I secured a set of some of these slides and from that time have endeavored to study the general problem. After several seasons of more or less systematic observation, however, without the aid of photography, of snow forms as found on the eastern slope of the Rocky Mountain range at the elevation of 6,000 feet, together with a study of Mr. Bentley's paper, I began to reach some interesting conclusions. These were published in April, 1905 and June, 1906.[2] in the "Colorado College Studies."

An important part of Mr. Bentley's work is contained in the tables he gives showing the distribution of the various types of crystals with respect to (1) storm section, (2) temperature, and (3) cloud source. This is summarized in the following tables taken from my former paper.

The crystals in the tables are divided by Bentley into seven classes as follows: (1) Columnar, (2) solid tabular, (3) stellar-nucleus (having solid centers), (4) fern-stellar, (5) doublets, (6) needle-shaped, and (7) granular.

TABLE 1.—*Distribution of snow crystals of various types for 131 general Vermont storms, years 1897 to 1902.*

Storm section.	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
N	22	19	25	17	3	6	8
NE	14	19	24	10	14	5	14
E	22	11	15	26	4	11	11
SE	25	25	25	25	0	0	0
S	0	5	10	40	5	10	26
SW	13	16	19	23	8	3	18
W	9	21	25	22	5	5	13
NW	5	20	23	22	7	22	20
Central	12	12	18	19	13	8	17
Undetermined	8	16	26	20	0	2	26
Distribution for 14 local storms, 1901-2	7	0	13	27	0	0	53
Grand total for all cases	11	16	21	23	4	5	20

[1] Presented before the Pacific Section, A. A. A. S., Pasadena, Calif., June 19, 1919.
[2] See also Rev. Nephol. Bruxelles, 1907, pp. 145-150.

152416—20——1

TABLE 2.—*Distribution of crystals with respect to temperature.*

Storm section.	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Medium cold storms +15° F. to +5° F.	23	20	17	14	5	3	20
Very cold storms +5° F. to −10° F.	10	22	26	23	5	4	11

Prof. G. Hellmann in an interesting little book entitled "Schneekrystallen," printed in Berlin in 1893, cites figures for the three types (2), (3), and (4). Taking these types by themselves the following table results:

TABLE 3.

Temperature.	(2)	(3)	(4)		Observer.
	Pct.	*Pct.*	*Pct.*	*Pct.*	
21.2° F. to 18.5° F.	26	22	52	31	Hellmann (Berlin).
15.8° F. to 9.5° F.	57	19	24	21	
15° F. to 5° F.	40	34	28	39	Bentley (Vermont).
+5° F. to −10° F.	30	37	33	47	

TABLE 4.—*Distribution of crystals with respect to cloud sources during 67 storms, winter of 1901-2 (Bentley).*

Character of clouds.	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Cumulo-nimbus	2	0	15	35	0	7	41
Stratus and nimbus	20	13	20	27	13	6	0
Cirro-stratus and nimbus	6	16	20	20	4	6	28
Stratus	16	33	33	0	0	0	16
Cirrus	0	0	0	0	0	0	0
Cirro-stratus	32	23	23	18	0	5	0
Cirrus and cumulus	11	11	22	22	11	0	22

In considering the foregoing tables the following remarks by Mr. Bentley should be carefully noted: "It will be noted that the cirrus and cirro-cumulus clouds have deposited no snow crystals. These clouds, when occurring alone, very rarely, if ever, deposit crystals of sufficient size to fall to the earth. * * * When nimbus or stratus clouds are present the existence of cloud strata lying above the lower clouds can not be certainly determined, but have been inferred from general considerations. In general, the snow forms are most frequent when two or more cloud strata exist. * * *"

For a more complete discussion of these tables both Mr. Bentley's and my articles should be consulted. The conclusions which I reached from their study are as follows:

(1) The open-structure type of crystal (frequently called the "Fern-stellar" type) is on the whole of the most frequent occurrence. Bentley himself remarks: "The preponderance of the branching open-structure crystals and granular forms will be noted, and it may be added that such types actually form a larger percentage of the total mass of crystals than is indicated by the figures.

(2) They are numerous in the case of local storms; in general storms they seem to be most numerous in the southern segment.

(3) They are more frequent at low temperature than at high temperature (Bentley). The reverse is true (Hellmann). The contradiction here found may be ascribed to the small number of cases examined by the respective observers.

As the number of observations increased, I should expect Prof. Hellmann's conclusion to be verified rather than Mr. Bentley's. To this, however, there would be notable exceptions [see (8) below] for the question of surface temperature is far from conclusive. Other factors would need to be considered, such as the humidity, both absolute and relative—the presence or absence of more than one cloud stratum; atmospheric turbulence and wind velocity, conditioning the length of time the crystal is kept aloft.

(4) They are abundant in the case of low-lying clouds.

(5) Crystals having solid centers are most frequent in the case of high-lying clouds. At low temperatures these classes gain at the expense of the granular type.

(6) The granular type occurs frequently when the the temperature is high and in local storms; it is not frequent at low temperatures.

(7) The doublets and needle-shaped crystals are infrequent at best and occur about equally at all temperatures; double-cloud strata seem to be favorable to their formation.

(8) In the case of light snow, falling sometimes from an apparently clear atmosphere, careful observations in Colorado convinced me that the crystals from low altitudes, below 3,000 feet, are always of the open-structure type while those from high altitudes are preponderantly of the closed-structure type. My paper of June, 1906, is taken up with a discussion of this point.

(9) In regard to some of the rarer forms, doublets and needle-shaped forms, when they occur they come in large numbers as if the conditions which produced them precluded the formation of the more common tabular type.

With the preceding studies as a basis it seems possible to formulate the following general hypothesis in regard to the formation and transformation of tabular snow crystals:

First.—All snow crystals of the tabular type have their origin in the open-structure crystal. (See figs. 1 to 12.)

Second.—The solid hexagon is the final form to which all tabular crystals tend. (Figs. 29 to 34; 136 to 145; 170 to 172.)

Third.—There is a transformation from the primitive to the final forms, this process being subject to many varying conditions which leave their impress upon the crystal.

Fourth.—There are two general transition processes; first a process of accretion in which new material is added to the crystal; second a process of transformation in which the losses and gains result in a change in arrangement of material, a reduction in size and generally in mass also.

The process of accretion is to be regarded as a rapid one taking place whenever the crystal is in an atmosphere tending toward supersaturation. Under these conditions the growth is of the "fern-leaf" type and is readily recognized. (Figs. 12, 48, 152.) The rapidity of growth is shown in the lack of symmetry.

On the other hand, the transformation process takes place in an undersaturated region and consists not only of losses due to gradual evaporation from the outlying parts of the crystal but also to gains due to still more gradual condensation about the center of the crystal. The slowness of the process is shown in the filling in of the open spaces, in the completion of the hexagonal figure of the crystal and still more in the wonderful symmetry manifested in every detail of the pattern developed. Time is the essential element in this process.

Upon this hypothesis it is now possible to arrange a classification of crystals which shall show, at least approximately, where the crystal belongs, what its history has been and something as to its age. It seeks to place the crystal in accordance with the successive stages of development through which it has passed. The classification is as follows:

Class I. First-growth Crystals.

I_a. Axes of crystallization alone prominent. Fig. 1 illustrates this crystal.

I_b. Axes with rapid growth additions. Fig. 8 is a good sample, while fig. 12 seems to show the limit of this stage.

I_c. First growth crystal modified by evaporation and condensation. This type is frequently met with. Fig. 15 is a good sample.

I_d. Final completed crystal of first growth. Fig. 29 is a fine example.

Class II. Second-growth Crystals.

II_a. Secondary axes prominent outside of the *first-growth* center; fig. 38 will illustrate.

II_b, II_c, II_d, have the same significance as under the First-growth Crystals. Numerous cases will be found in the photographs which follow.

Class III. Third-growth Crystals.

$III_{a, b, c, d}$ have the same significance as above.

Class IV. Fourth-growth Crystals.

This is the highest stage of growth that I have observed. I do not find any examples in the data herewith presented.

Class V. Special or unusual forms. Here we frequently find that the pathological rather than the normal cases prove the most informing and furnish the most suggestive data.

The above classification has been made to apply primarily to the tabular form of crystal. The columnar and other forms present equally interesting problems, which at present seem to be somewhat more difficult of solution. The groups of crystals 196, 197, 198, some 15 in number, illustrate this class.

The observations of the past 19 years have tended to increase my confidence in the conclusions set forth above. Removal to southern California has put a stop to direct observation, but I have found abundant material for study in photographs furnished me by Mr. Bentley.

The present paper, in so far as it presents new material, is a study of the complete crop of photographs secured by Mr. Bentley during the winter of 1916–17. This selection was made partly because of the enthusiasm with which he spoke of the variety and beauty of that season's crystals. His enthusiasm was entirely justified.

The number of tabular crystals is 211. There are also some 15 of the columnra and doublet types. Some of the "special" crystals have proved especially interesting.

There are several features among the present collection of photographs which call for more than a passing word.

First, it is well worth while to pause for a moment and consider the line patterns of many of the crystals They constitute one of the, as yet, unsolved problems connected with snow-crystals. It is the opinion of students of the subject that these lines are air tubes. G. Hellmann of Berlin discusses them as follows:

> The most remarkable feature of the structure of the primary and secondary rays lies in the capillary cavities which they contain. * * * Attention was called to them as early as 1681 by Rossetti and by Wilcke at a later time. * * * It was in the laminar snow crystal that I observed them for the first time, for they are usually larger there and thus more easily seen * * * the inner distance between the capillary tubes is ordinarily from 0.02 to 0.05 mm. and the largest diameters of the tubes themselves are of about this order of magnitude. * * *

Second: Several of the individual crystals reward careful study. These fall into the following groups;

(1) Nos. 188, 189, 190.
(2) Nos. 76, 199, 200.
(3) Nos. 184, 185.

Taking these in order; (1) It is evident that these three crystals were broken and afterwards repaired themselves to the extent shown. In all three cases it must have been necessary for the impaired crystal to pass into a region of high humidity, to build up secondary axes and then for the growth on these axes to consolidate. In each of these cases it would appear that the secondary axes formed only on the impaired portion of the crystal. In crystal 189 and 190 we further note that on the repaired portion of the crystal the pattern of the older portion is reproduced.

From the above we are led to conclude:

I. That the force of crystallization, assisted it may be by attendant circumstances of temperature—humidity and electrical state—is much stronger as one approaches the center of the crystal.

II. The restoration of the pattern, as well as the material of the lost part of the crystal, would indicate that the law of symmetry means more than has heretofore been assigned to it. The infinite variety in designs found may be due in their inception to fortuitous circumstances, but the pattern once started is fixed to a degree hitherto unthought of.

(2) Crystals 76, 199 and 200 should be studied together. In 76 and 199 the channels between the sextants are open and extend almost to the center of the crystal. In No. 200 these channels, originally open, are now completely closed. Moreover, the outline of the "filling," showing all the irregularities originally present, seems to show a rapid process of filling in, as if the inhibition had been suddenly lifted and the process of filling rapidly carried out. In my first paper (May, 1905) I made a suggestion in regard to crystals of the form of 199 substantially as follows:

It is permissible to suppose that the particles thrown off by evaporation may carry with them an electric charge, leaving the surface from which they come charged in an opposite sense. Now since the evaporation would be more active at the tips of the crystal than in the angles, the former region would have a stronger charge than the latter. In this way a difference of potential would be established between tip and angle and the charged vapor particles would have a tendency to follow this potential gradient. In other words there would be a net loss of material to the crystal but there would be a transfer from the tips into the angles of the crystal thus tending to build up the solid form of crystal. Next let us suppose (e. g.) that the tips of the crystal are positively charged and the angles negatively charged. Also that the vapor particles in the general region are negatively charged.

The result now would be that since the walls of the angles are negatively charged and the free vapor particles negatively charged, the free particles attaching themselves to the crystal would be less and less deposited on the walls of the angles, thus leaving the channels open and building up the outer portions of the crystal. This effect would only be operative at temperatures low enough to render the crystal a comparative nonconductor, otherwise the charges would be dissipated by conduction.

Finally, if a crystal of this type were to next pass into a stratum which is at a higher temperature, or where the vapor particles are positively charged or neutral; the result of the first would be to dissipate the screening charge by conduction, thus permitting the deposit of vapor particles upon the screened portion, while the second would invite such deposit. In either case, the channel would be rapidly filled up as shown in fig. 200.

(3) Considering next Nos. 184, 185 at first these seem most unusual and strange. Further consideration, however, shows them to be but extreme cases of 199. Two quite different explanations seem possible, (a). Thus, glancing at Nos. 6, 7, 36, 40, 41, 47, 82, 148 and 152 we see that rudimentary growths have started at the middle of the sides of the crystals. Nos. 6 and 7 are first-growth crystals, 40 to 82 second-growth crystals and 148, 152 third-growth crystals. Such growths are of rare occurrence, being found on but 5 per cent of the present data.

If crystals of this sort were now placed under the conditions which produced Nos. 76 and 199 the result would be to produce Nos. 184, 185. These crystals are then to be classed under I_c, II_c or III_c. The fact that they are rarely found would be due to the double fact that the rudimentary start required is rare and the further condition producing 199 is rare.

(b) The second explanation is based upon a recent letter of Mr. Bentley in which he makes the following significant remark in regard to figure 185:

> I have several such. Crystals of this (seeming) shape are quite common in some snowfalls, possibly 1 per cent being of this shape for a brief time. But so far as I am able to learn, the 12-pointed ones really consist of one crystal *superimposed* upon another, and never growing outward on the *same plane*. It would seem as if there must be a short bar or connection at the center, for the rays of the one usually project at an intermediate direction *between* the rays of the other. Yet they are easily detached one from the other. Crystal 185 was so detached after photographing it.

This would connect many, if not all, crystals of the form 184–185 with the doublet crystals shown in No. 196. It would also make each member of such a doublet of the form of 199. The interesting feature is the fact that the axes, or rays, of the two members lie at a 30° angle with each other instead of being parallel as in 196. Remembering that the connecting bar between the two members is exceedingly short, and remembering that the rays of the crystals are electrically charged, it would seem possible to invoke the same electrical action already suggested as responsible for type 199, here also, thereby forcing the axes to place themselves at a maximum distance from each other, as shown in 184 and 185.

As no attempt is made in the present paper to discuss the doublet further comment is reserved for a future time.

Tubular summary of all crystals.

First growth.			Second growth.			Third growth.			Totals.		
Class.	I.	P. ct.	Class.	II.	P. ct.	Class.	III.	P. ct.	Class.	Cases.	P. ct.
	Cases.			*Cases.*			*Cases.*				
I_a......	3	=1.4	II_a....	7	3.3	III_a...	7	3.3	a	17	= 8.0
I_b......	10	4.7	II_b....	15	7.0	III_b...	2	1.0	b	27	=12.6
I_c......	22	10.3	II_c....	85	39.7	III_c...	18	8.4	c	125	=58.4
I_d......	12	5.7	II_d....	15	7.0	III_d...	3	1.4	d	30	=14.0
Total.	47	22.0	Total..	122	57.0	Total..	30	14.0	Total..	199	93.0
									Special	15	7.0

The foregoing analysis of a considerable body of snow-crystal data has been given as an attempt to find, if possible, an adequate method of classification which shall lead eventually to a solution of some of the many interesting and at present apparently insoluble problems connected with this most fascinating subject.

My thanks are due to Mr. Bentley, from whom I sesured the photographs, and to Dr. Ford A. Carpenter, meteorlogist in charge of the Los Angeles Weather Bureau, and to my student, Harold P. Hamilton, who helped me in looking up references.

CLASS I. First-Growth Crystals.

I_a **Figs. 1, 2, 3; strictly speaking No. 1 alone belongs to this subclass, Nos. 2 and 3 having evidently received additional growth which has consolidated. Number of cases 3; =1.4 per cent of total.**

I_b **Figs. 4 to 12 inclusive (also fig. 186).** Number of cases 10; =4.7 per cent. There may be doubt whether No. 4 ought not to be placed under I_c. **The effect of such errors will be lessened as the number of crystals classified is increased.**

I_c **Figs. 13 to 28, inclusive; also Nos. 187, 188, 191, 192, 199, 200.** Number of cases, 22; =10.4 per cent. The crystals from No. 19 on might easily be placed in class I_d but it is better to include under I_d only those crystals which have absolutely reached the finished stage, as shown by the *completed* hexagon. It is interesting to note that the notch in the middle of each side seems to be the last part to fill in.

I_d **Figs. 29 to 34 inclusive; also Nos. 173, 174, 176, 178, 181, 182.** Number of cases, 12; =5.7 per cent. There may be some doubt as to whether Nos. 33 and 34 do not belong under Class II_d. At all events they afford beautiful examples of Nature's masterpieces in symmetry and design.

Total number of cases in Class I, 47; =22.2 per cent.

CLASS II. Second-Growth Crystals.

II_a **Figs. 35 to 41 inclusive.** Number of cases, 7; =3.3 per cent. All of these samples are excellent. On some the secondary growth has started, as in Nos. 35, 36, 40 and 41. The primacy of the axis is evident. The existence of rudimentary axes at the center of the sides in the case of Nos. 36, 40 and 41 should be noted. Further comment on this will be made later.

II_b **Figs. 42 to 56 inclusive.** These are excellent samples and show clearly the initial stage of the process of consolidation of the secondary growth.
Number of cases, 15; =7.1 per cent. It is a little puzzling to determine whether a crystal belongs under II_b or II_c. It is also difficult to determine the exact progressive order.

II_c **Figs. 57 to 135 inclusive: also Nos. 179, 183, 184, 185, 189, 195.** This class is by far the best represented of any. I find that Hellmann in his little book shows 56 photographs, of which 18 per cent belong to this class, as against 40 per cent for Bentley. The colder climate of Vermont would lead one to expect this.

No. 82 shows a well developed secondary axis at the middle of each side. It will be noted that the channels in No. 76 have been kept open clear down to the first order crystal.

Nos. 96–106: The process of consolidation is pretty well on towards completion. The symmetry of the interior pattern will be noted as well as the shaping up of the outer edge. In most cases the line of demarcation between the first and second order crystals is well defined.

Nos. 107–118: It is in crystals of this type that the most exquisite examples of snow-crystal handicraft are to be found. It must have been after contemplating such as these that Olaus Magnus of Upsala in 1555 suggested their use as patterns for designs. It seems strange that the idea has not been carried out in embroidery and stained glass effects.

Nos. 119–135: The crystals on the present plate have reached their final stage of growth. It is likely that most of the crystals that reach this degree of perfection do not complete their growth, or perhaps do so after reaching the ground.

Number of cases, 85; =40 per cent.

II_d. **Figs. 136 to 145 inclusive; also No. 194.** Number of cases, 15; =7.1 per cent.

Total number of cases under Class II, 122; =57.6 per cent.

CLASS III. Third-Growth Crystals.

III_a. **Figs. 146 to 150 inclusive, also No. 194.** Number of cases, 7; =3.3 per cent. In all of these crystals the third growth axis is rudimentary only. **This, however, is accidental** rather than general, for we shall see in the succeeding crystals well developed growths.

III_b. **Figs. 151, 152.** Number of cases, 2; =1 per cent. *Of these 152 is the better example,* both are meager.

III_c. Figs. 153 to 170, inclusive. All of these show a heavy growth of the third order. No. 155 is a good sample. No. 158 is an especially good sample. No. 162 is another showing the perfection of detail so often shown by these crystals.
Number of cases, 18; =8.5 per cent.

II_d. Figs. 170, 171, 172, 3 cases; =1.4 per cent. Total number of cases under Class III, 30; =14.2 per cent.

All of these crystals are included in the regular classification as follows:
No. 173, I_d; 174, I_d; 175, II_d; 176, I_d; 177, II_d; 178, I_d; 179, II_c; 180, II_d; 181, I_d; 182, I_d; 183, II_c.

They are grouped together because of some special feature of shape or pattern. Nos. 174, 176 are strangely like triangles though they still follow the hexagonal law of crystallization. It is unusual to find a circle in the line pattern. No. 180 approximates to this. No. 181 has the line pattern broken up into dots, while 182 has a drapery-like pattern which is unusual. No. 178 probably was broken and has been "mended" by the fairy workmen.

All of these crystals are included in the regular classification as follows: No. 184, II_c; 185, II_c; 186, I_b; 187, I_c; 188, I_c; 189, II_c; 190, II_d; 191, I_c; 192, I_c; 193, II_d; 194, III_a; 195, II_c.

Nos. 184, 185 belong in a class by themselves, apparently, but closer study will link them with Nos. 199 and 200 and also with crystals 196. Nos. 186, 187, 188, 189 and 190 have been in the repair shop and have an interesting story to tell.

Nos. 193, 194 and 195 have passed through a fringe of cloud liquid and have caught some of the drops. More of this would give a granulated crystal. No. 195 seems to have been falling without whirling, since one edge has caught all of the drops. This is only occasionally found.

Of these crystals, Nos. 199 and 200 belong in the regular classification: both fall into class I_c. They are however, to be especially studied because of the channels running nearly to the center in each case.

The crystal at the center of the plate is probably a columnar crystal with one end melted down. It may however, be one of the "Flagon" crystals sometimes found. In such case the interior ought to contain a large drop of water. The appearance of the crystal does not seem to indicate this.

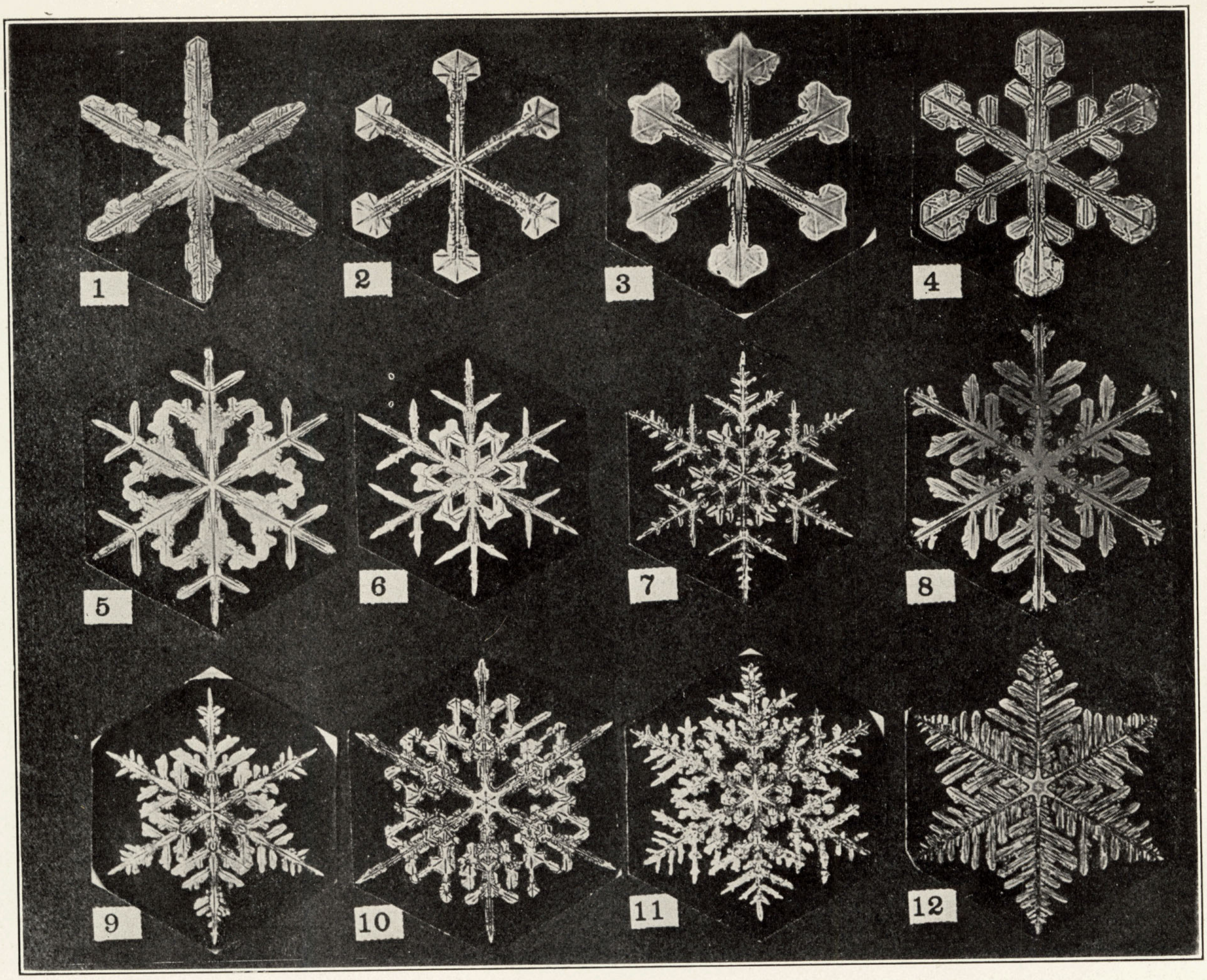
CLASS IV. No Fourth-Growth Crystals were found among the present data.

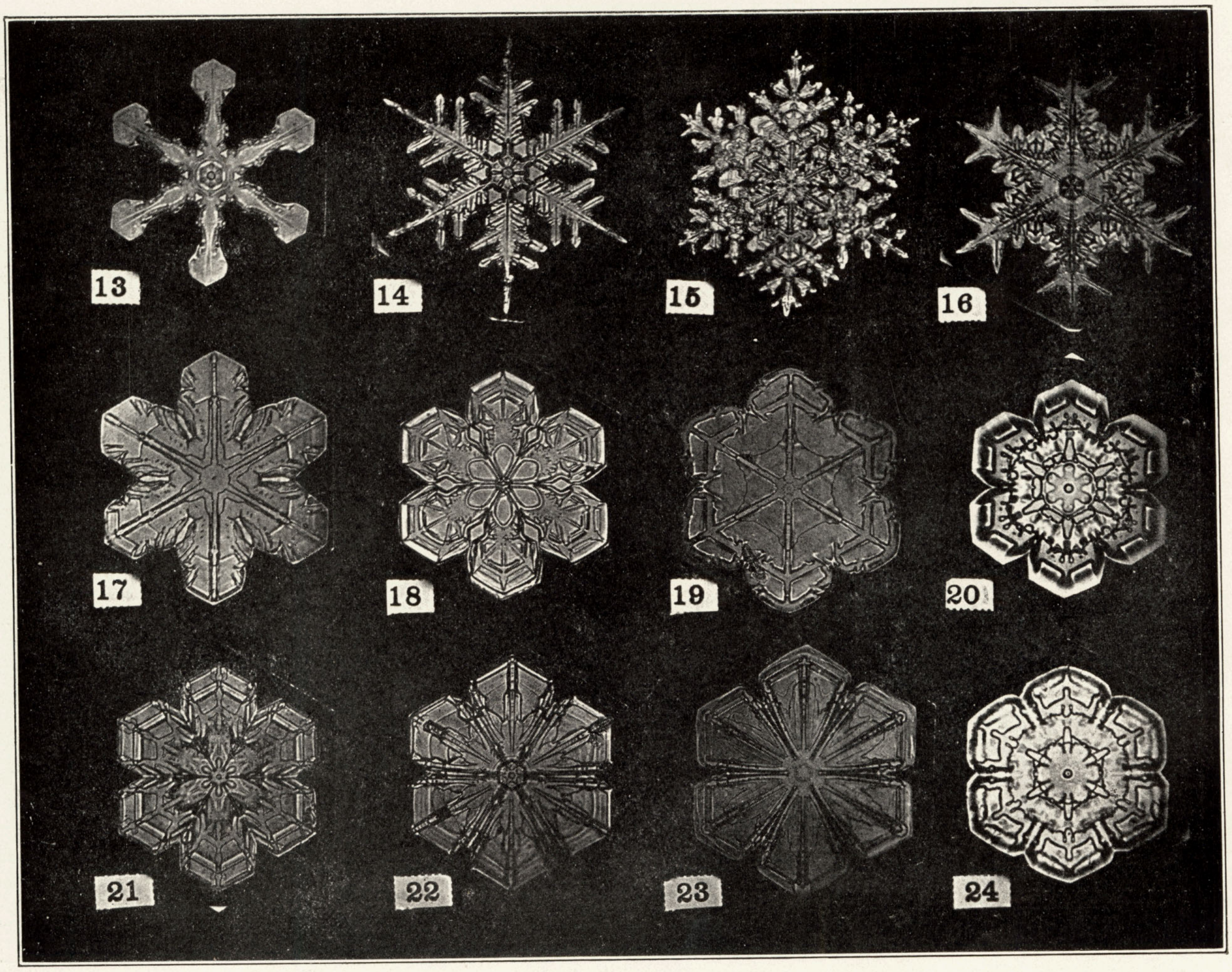
CLASS V. Special or unusual forms.

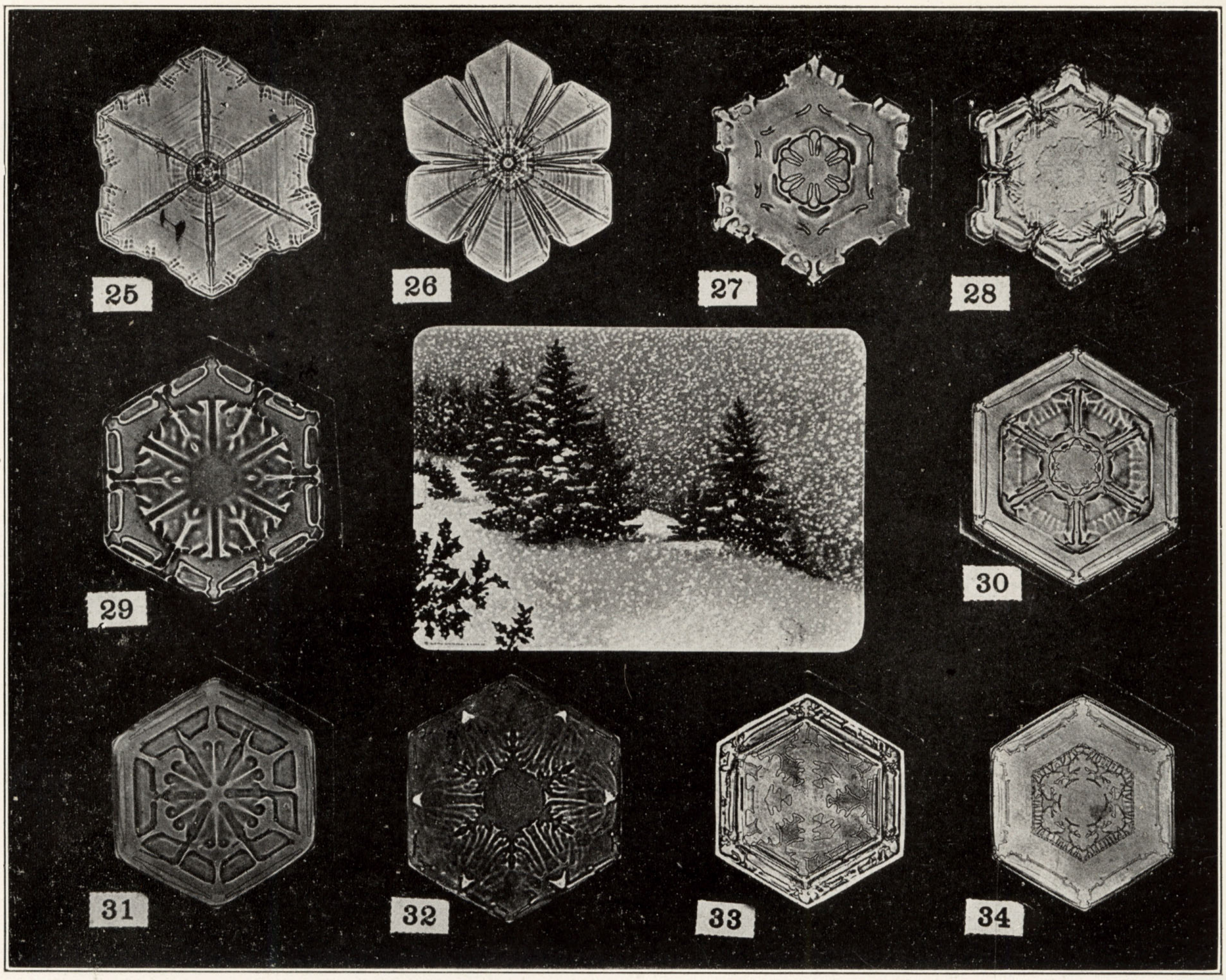
1. Columnar crystals; groups 197, 198, 11 cases; =5.2 per cent.
2. Doublets; group 196, 3 cases, 1.4 per cent.
3. Pyramidal crystals: group 197, 1 case.

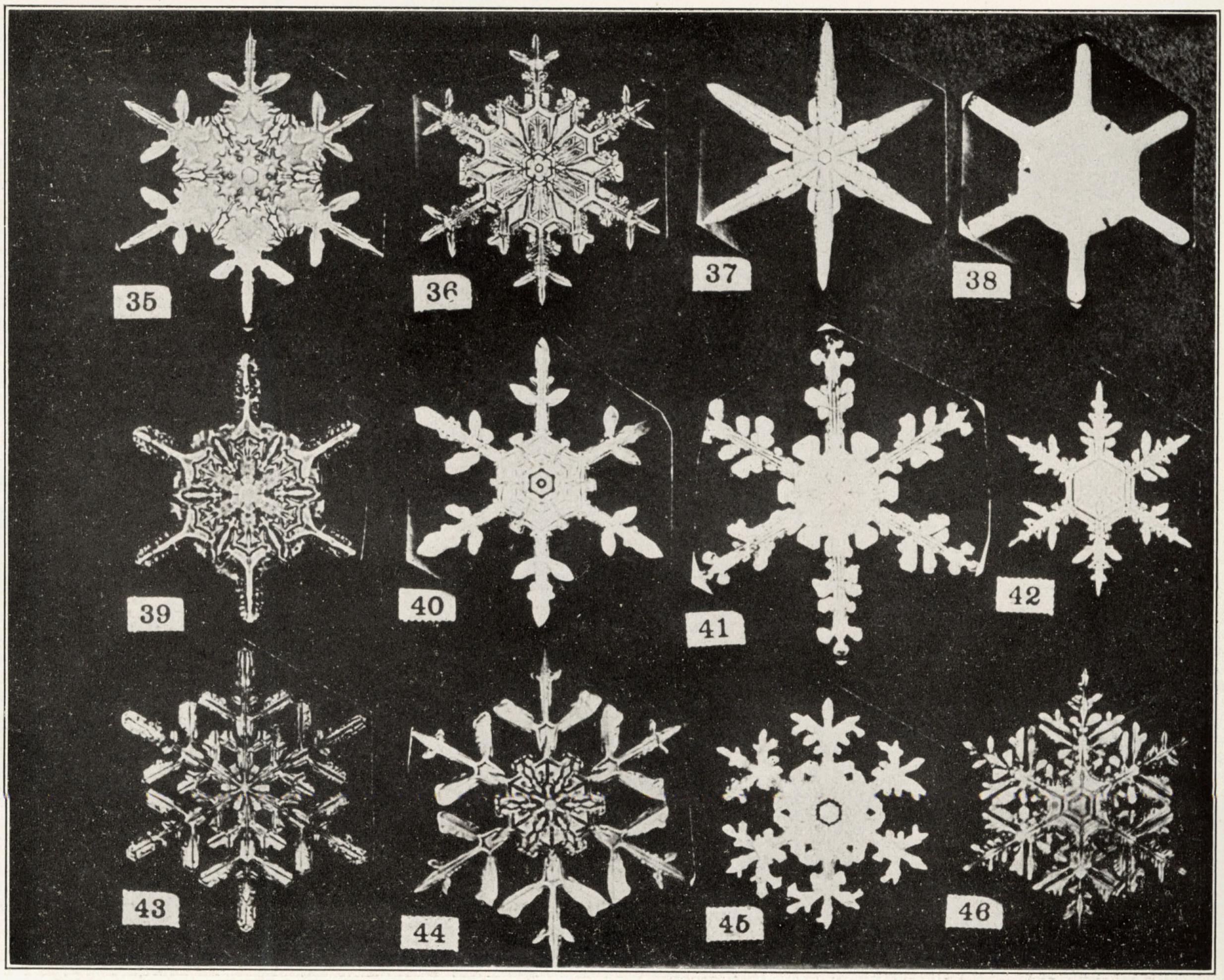
Total of special cases, 15; =7.1 per cent.

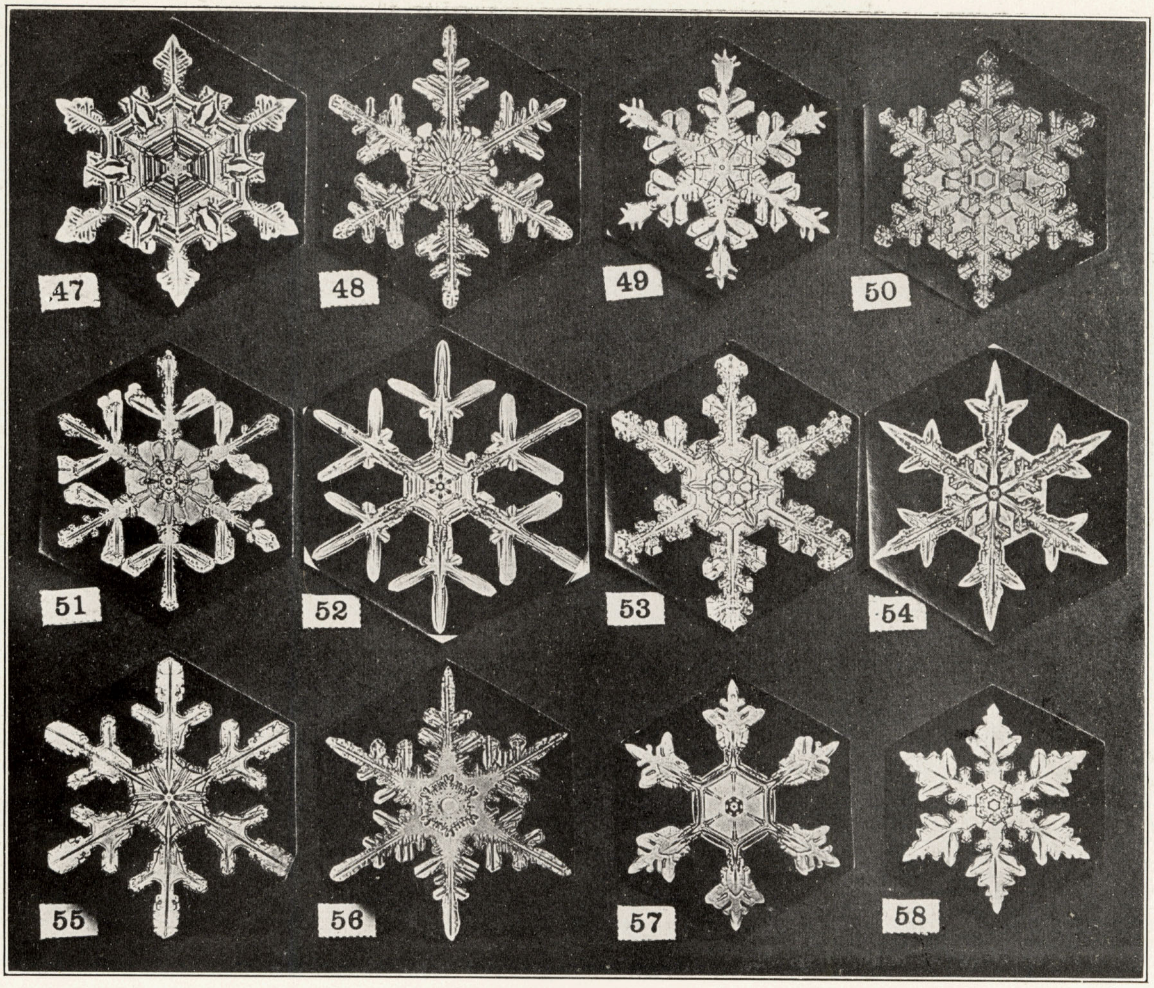
[To face p. 694.]

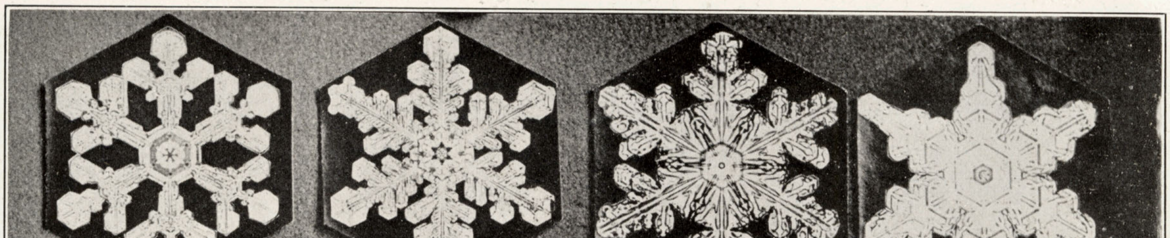


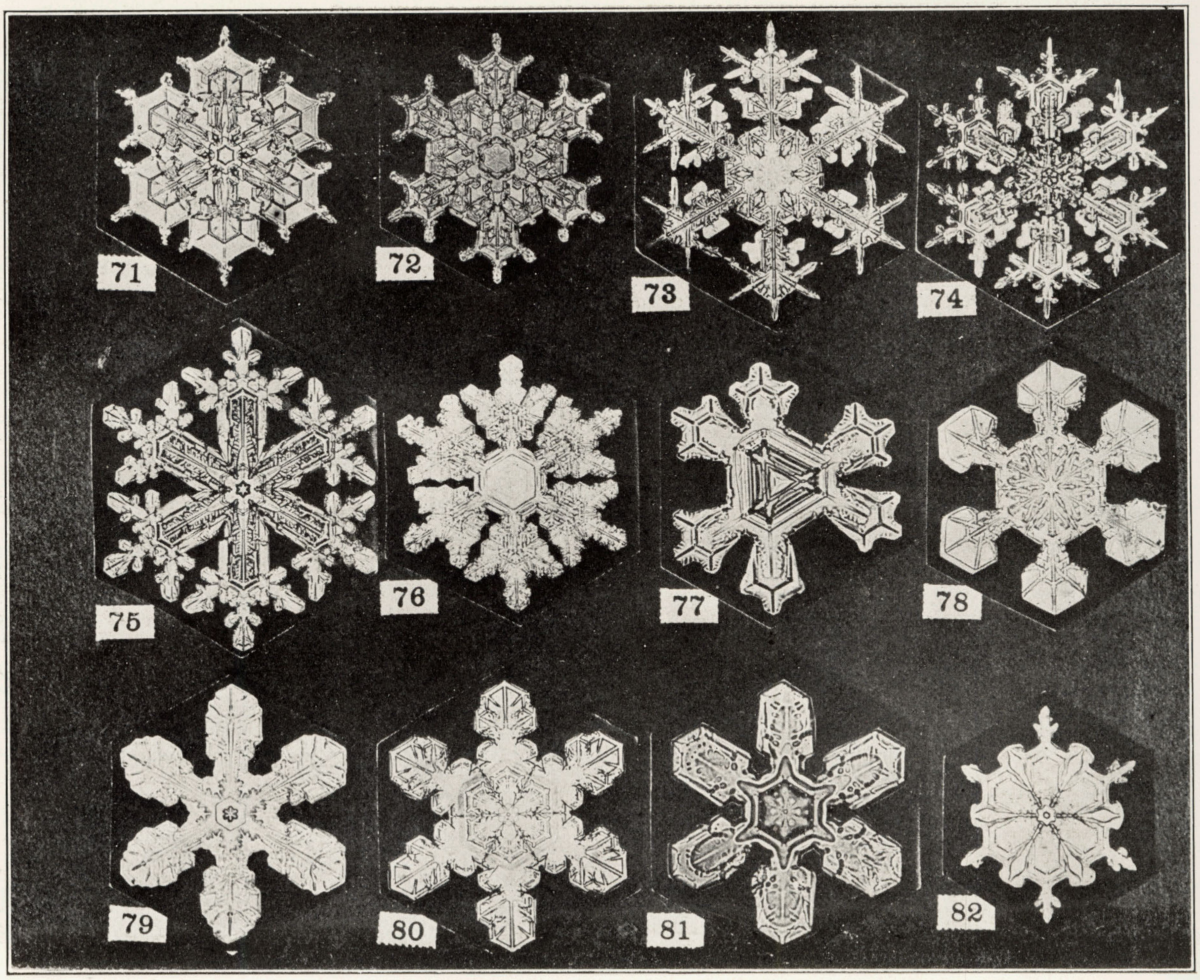


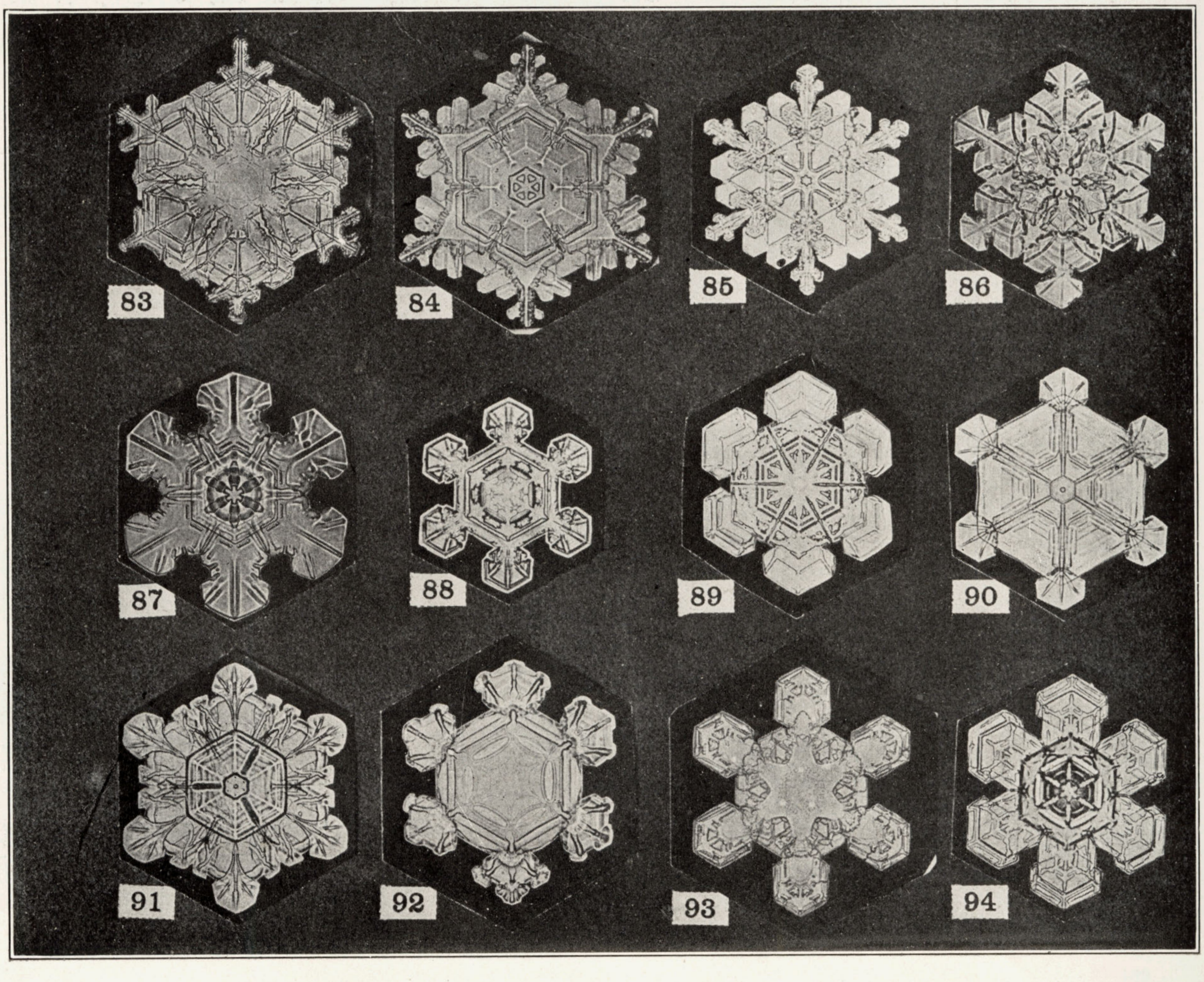

25
26
27
28
29
30
31
32
33
34

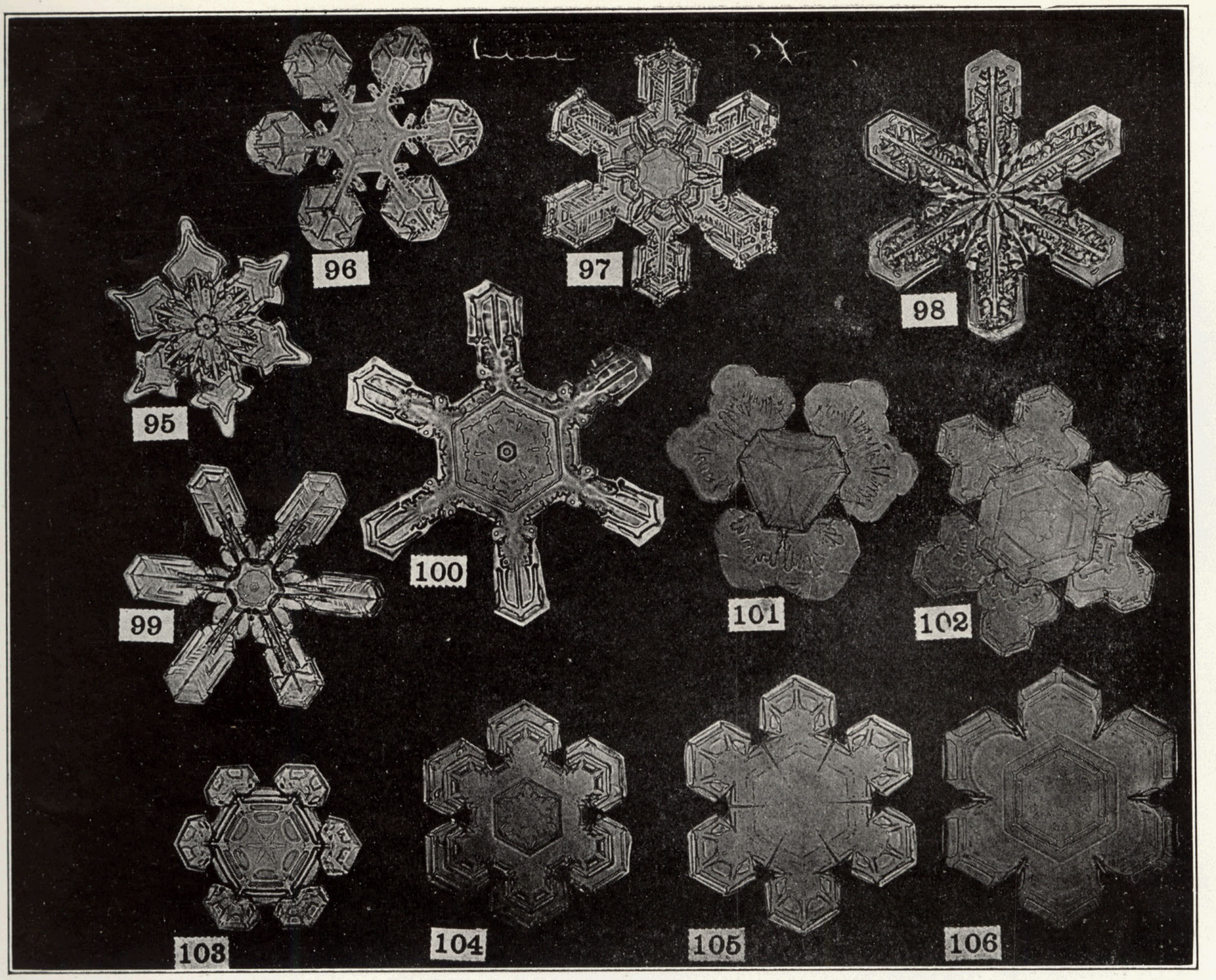

35
36
37
38
39
40
41
42
43
44
45
46

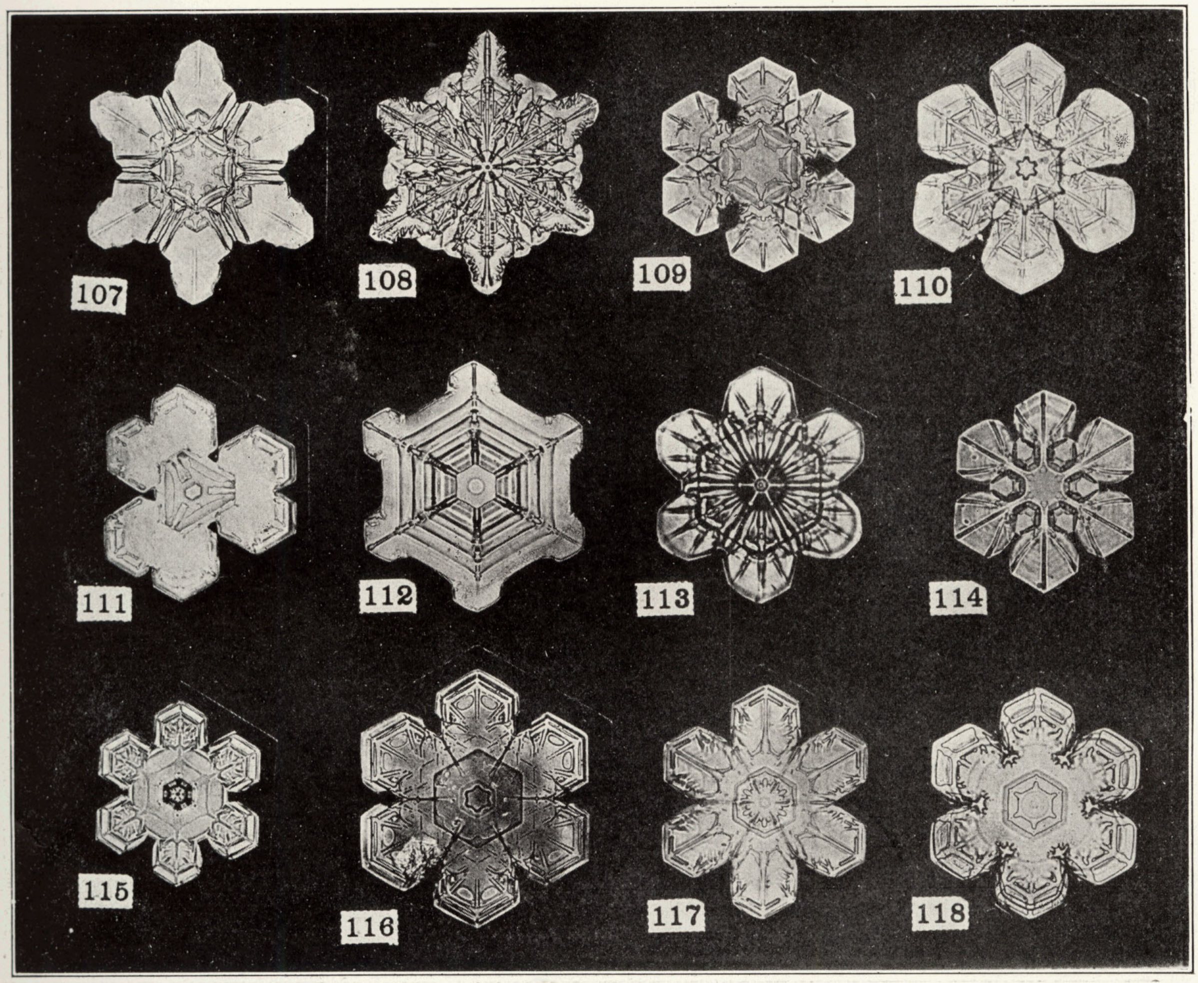

47
48
49
50
51
52
53
54
55
56
57
58

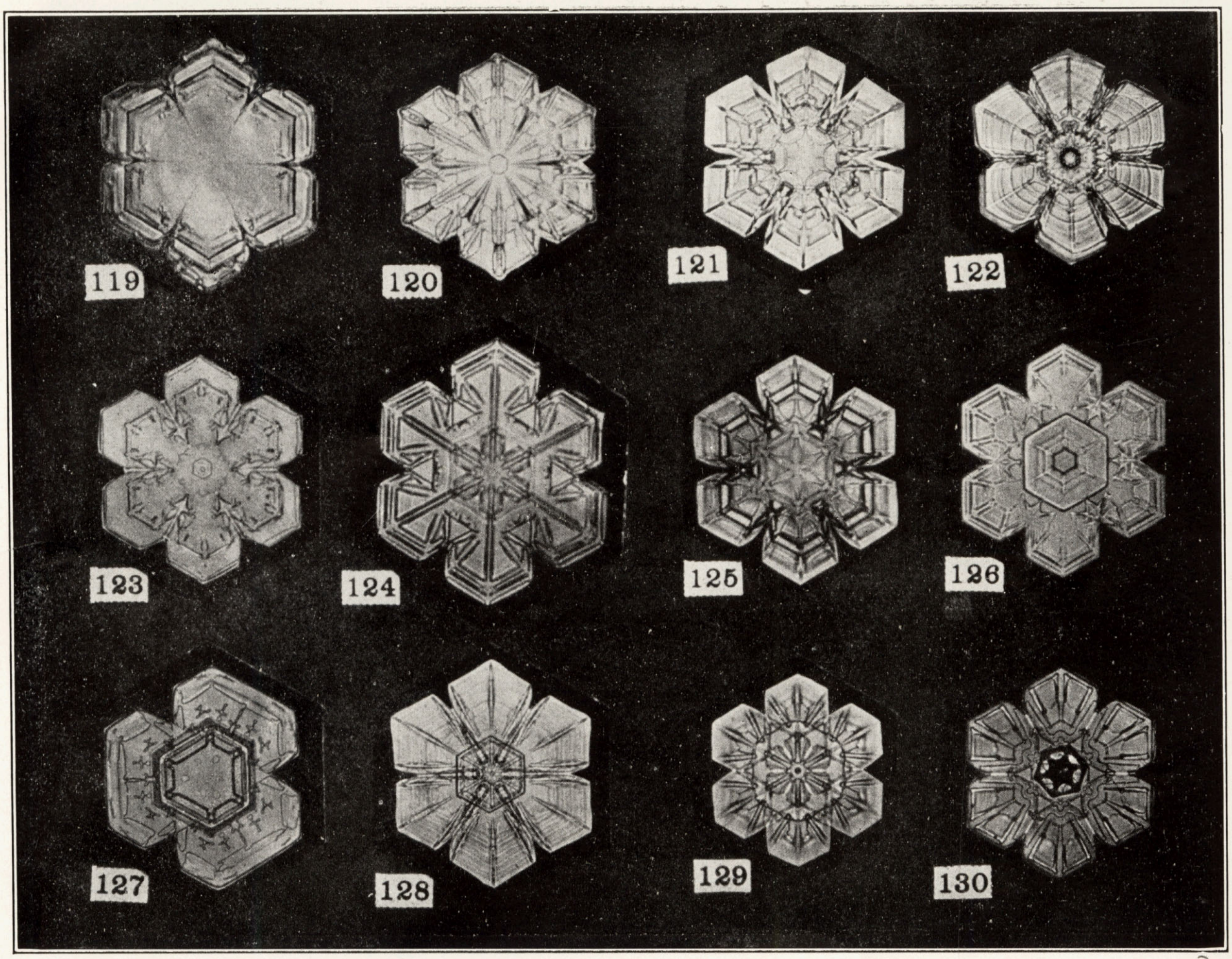

59
60
61
62
63
64
65
66
67
68
69
70

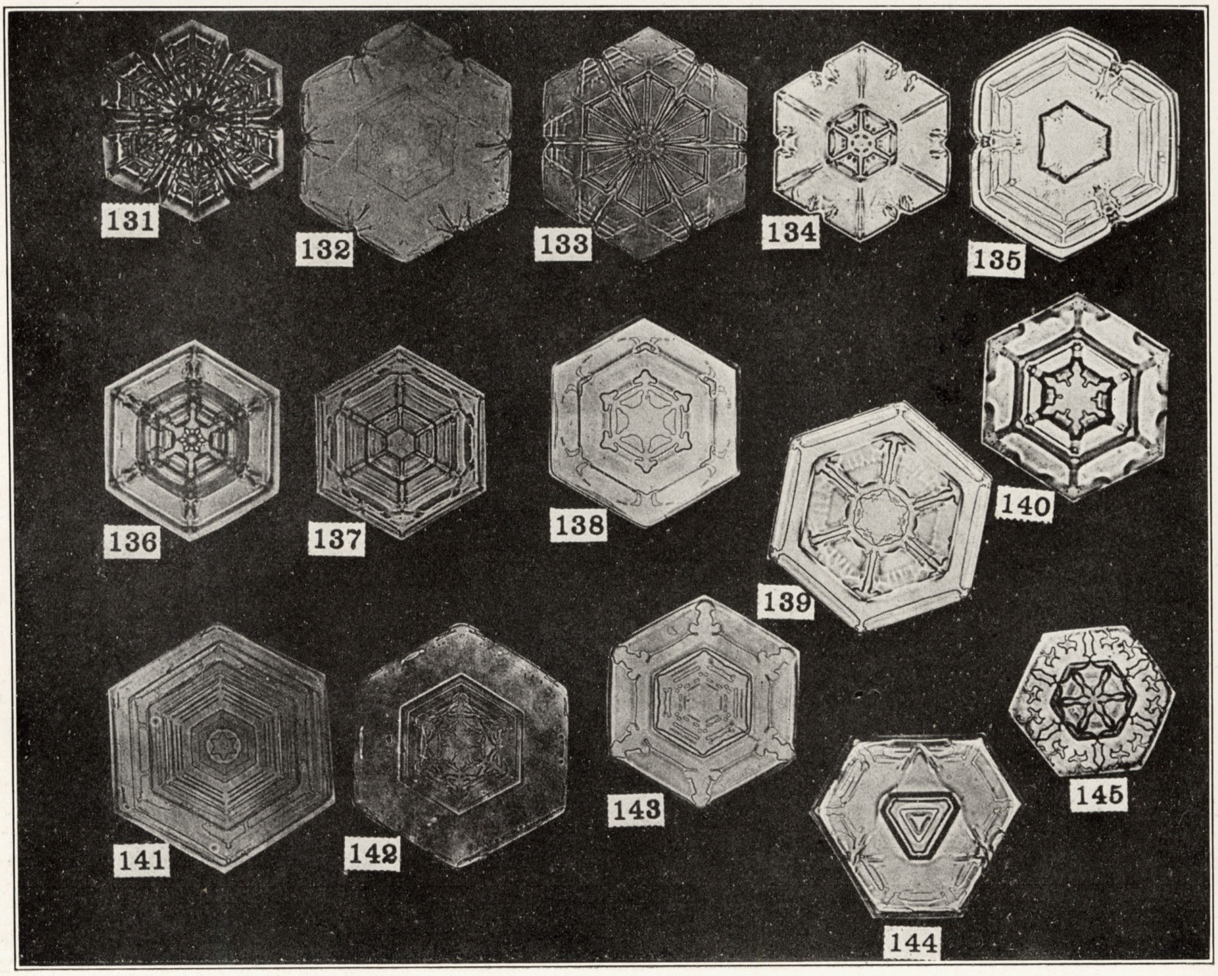

71
72
73
74
75
76
77
78
79
80
81
82

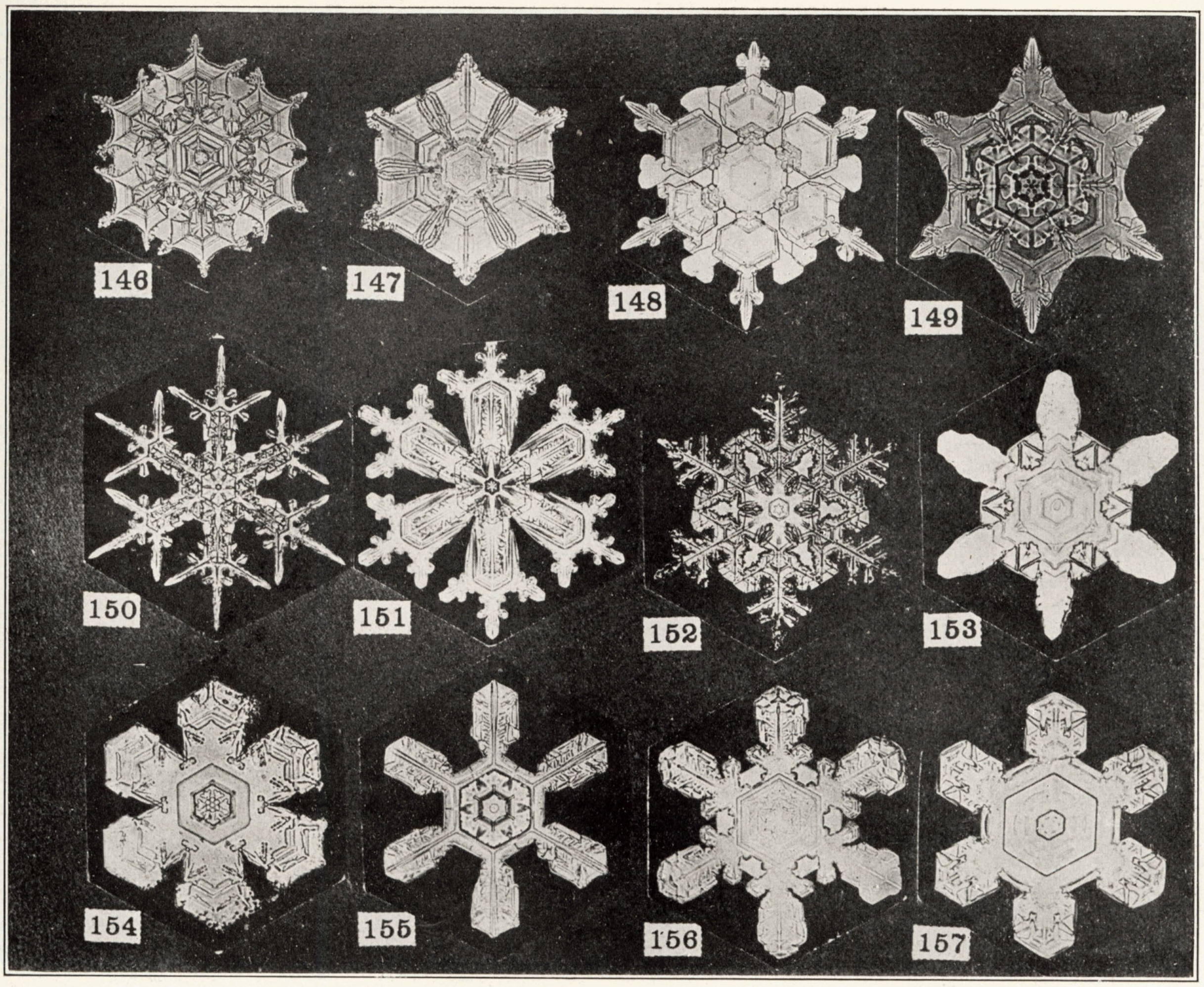

83
84
85
86
87
88
89
90
91
92
93
94

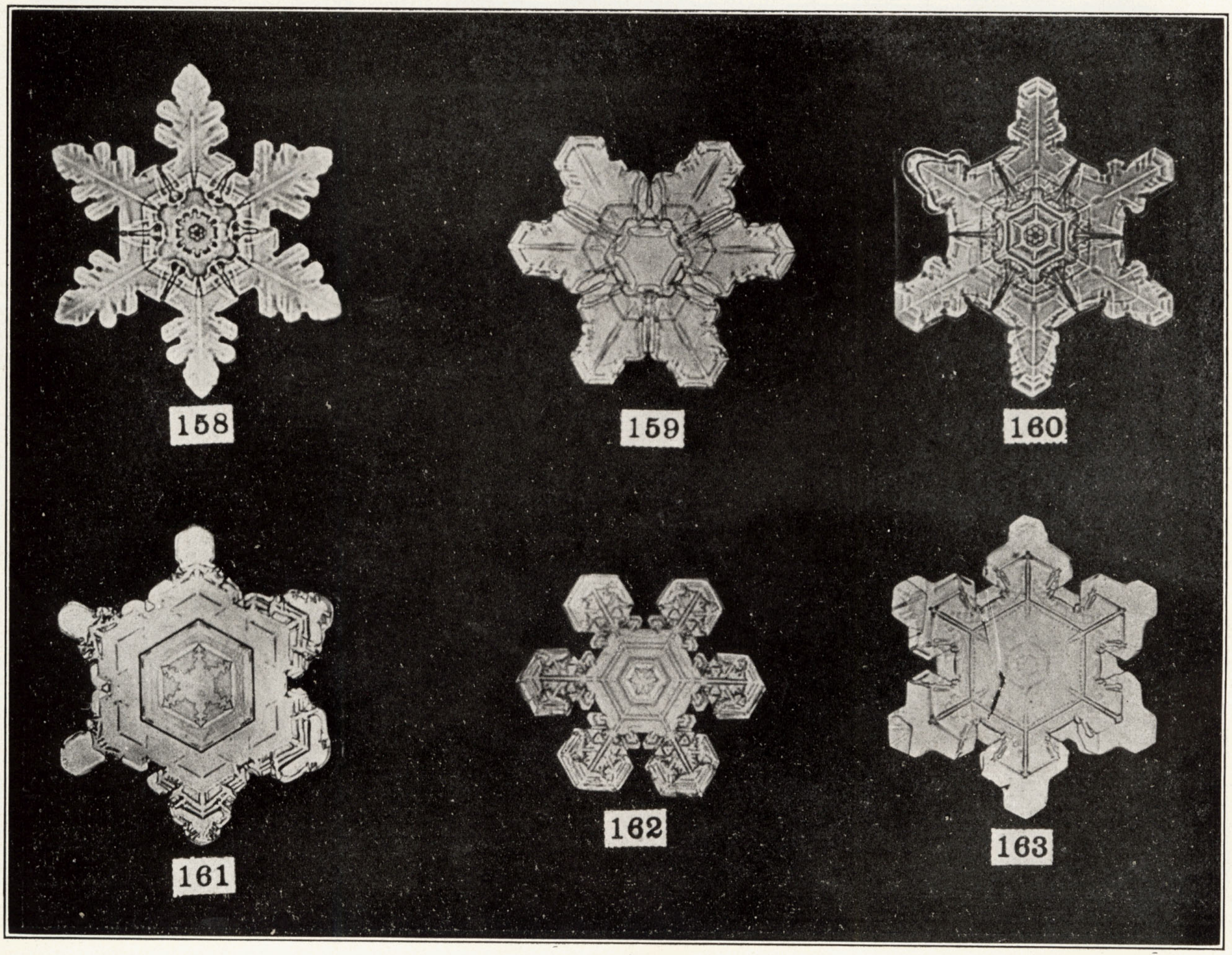

95
96
97
98
99
100
101
102
103
104
105
106

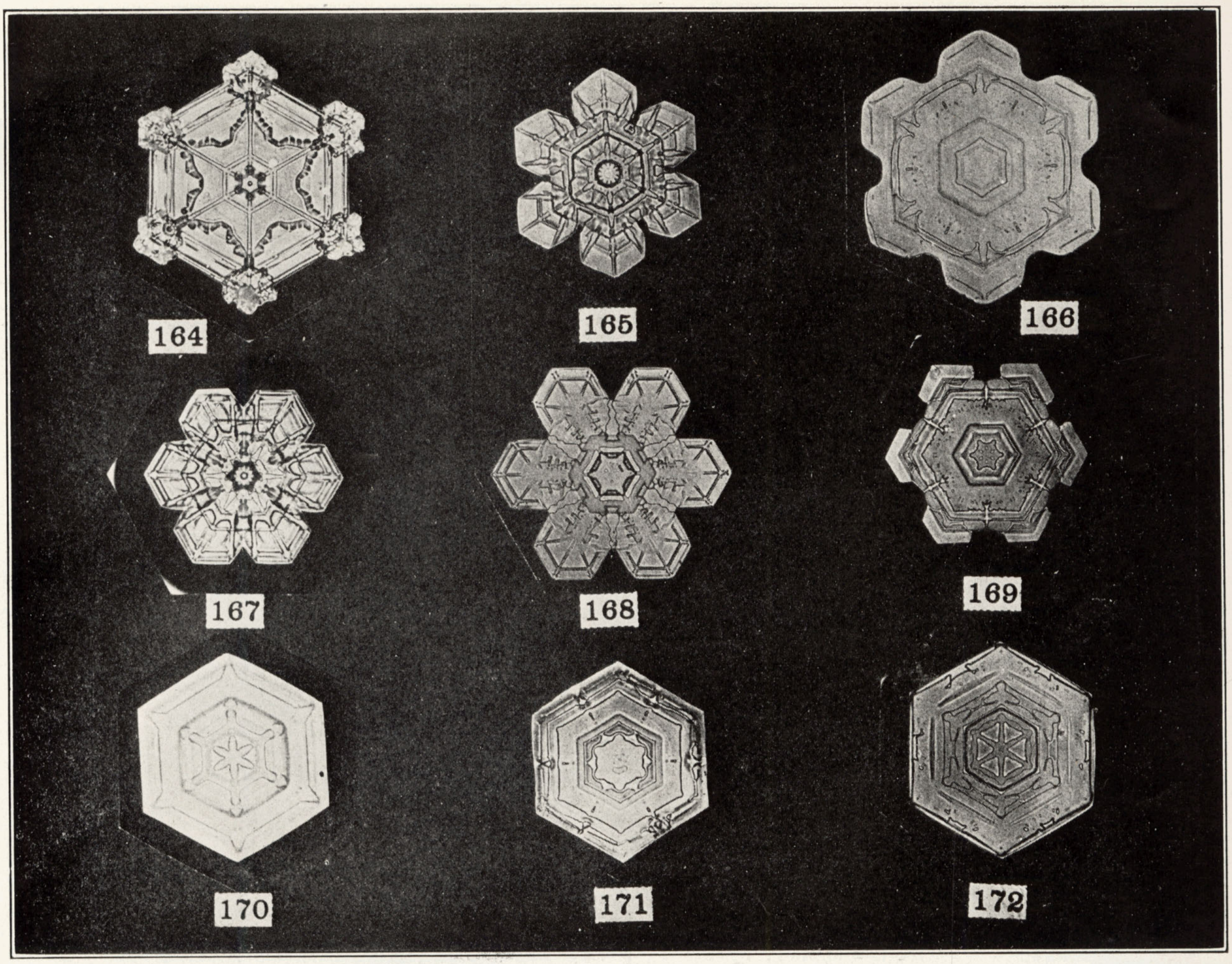

107
108
109
110
111
112
113
114
115
116
117
118

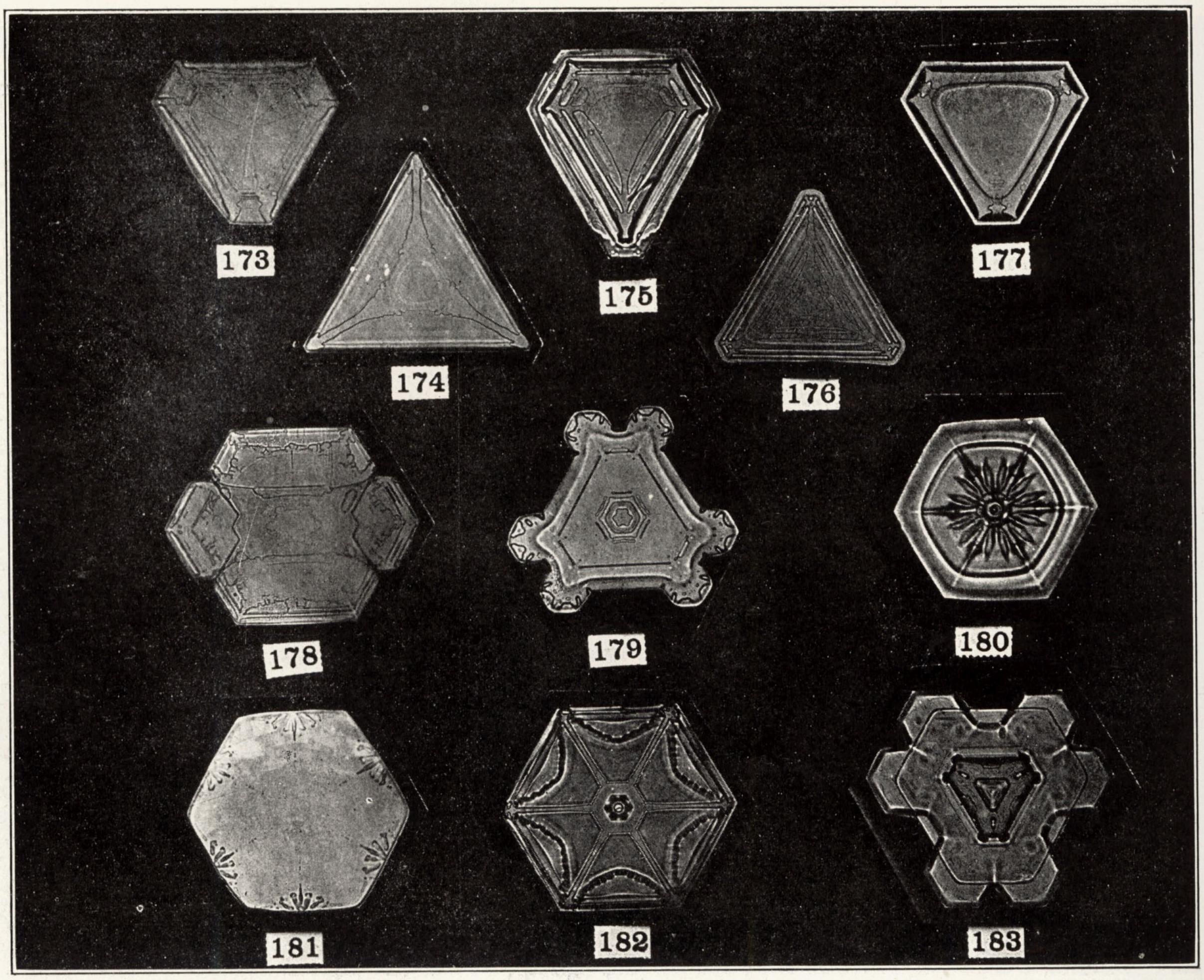

119
120
121
122
123
124
125
126
127
128
129
130

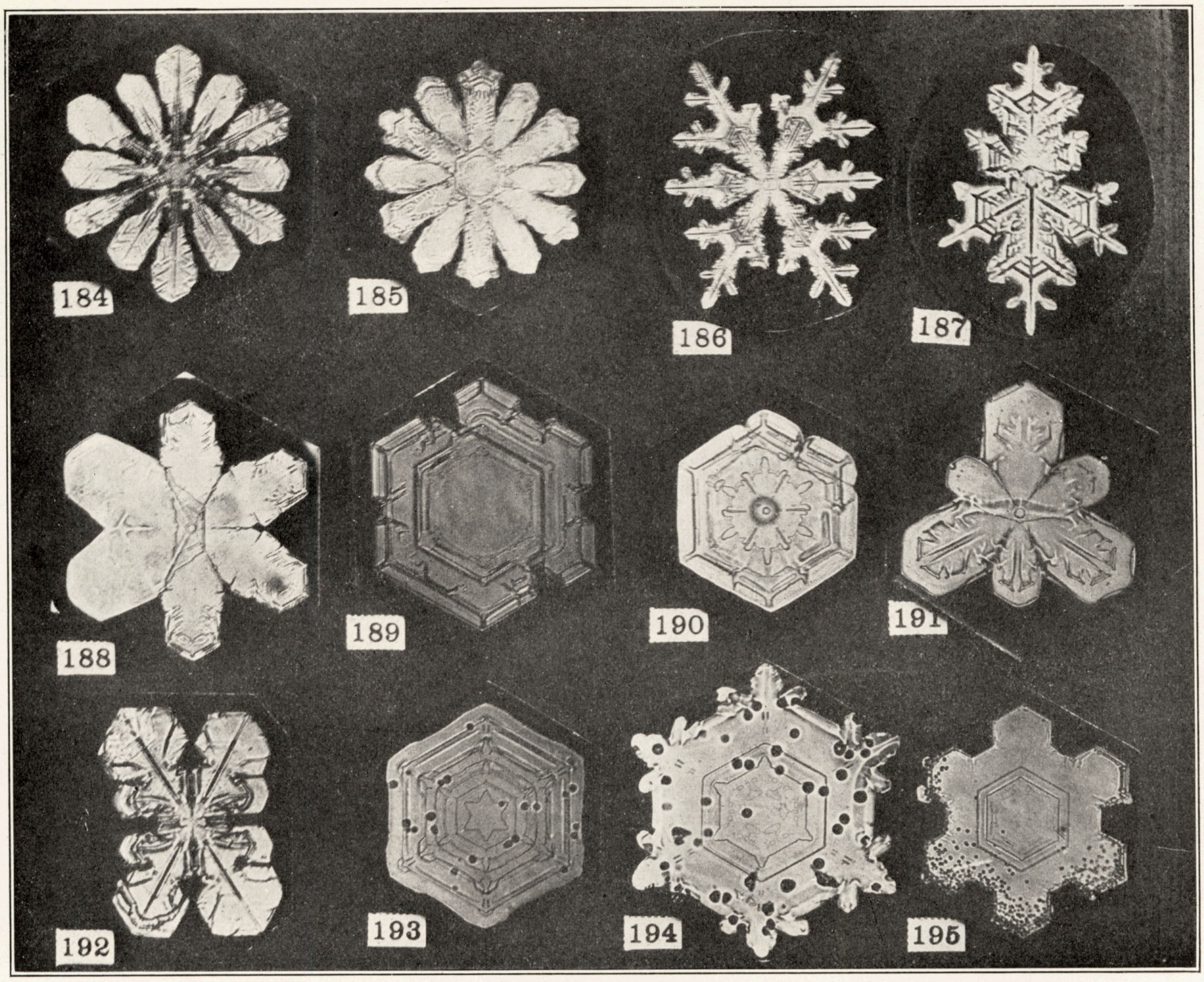

131
132
133
134
135
136
137
138
139
140
141
142
143
144
145

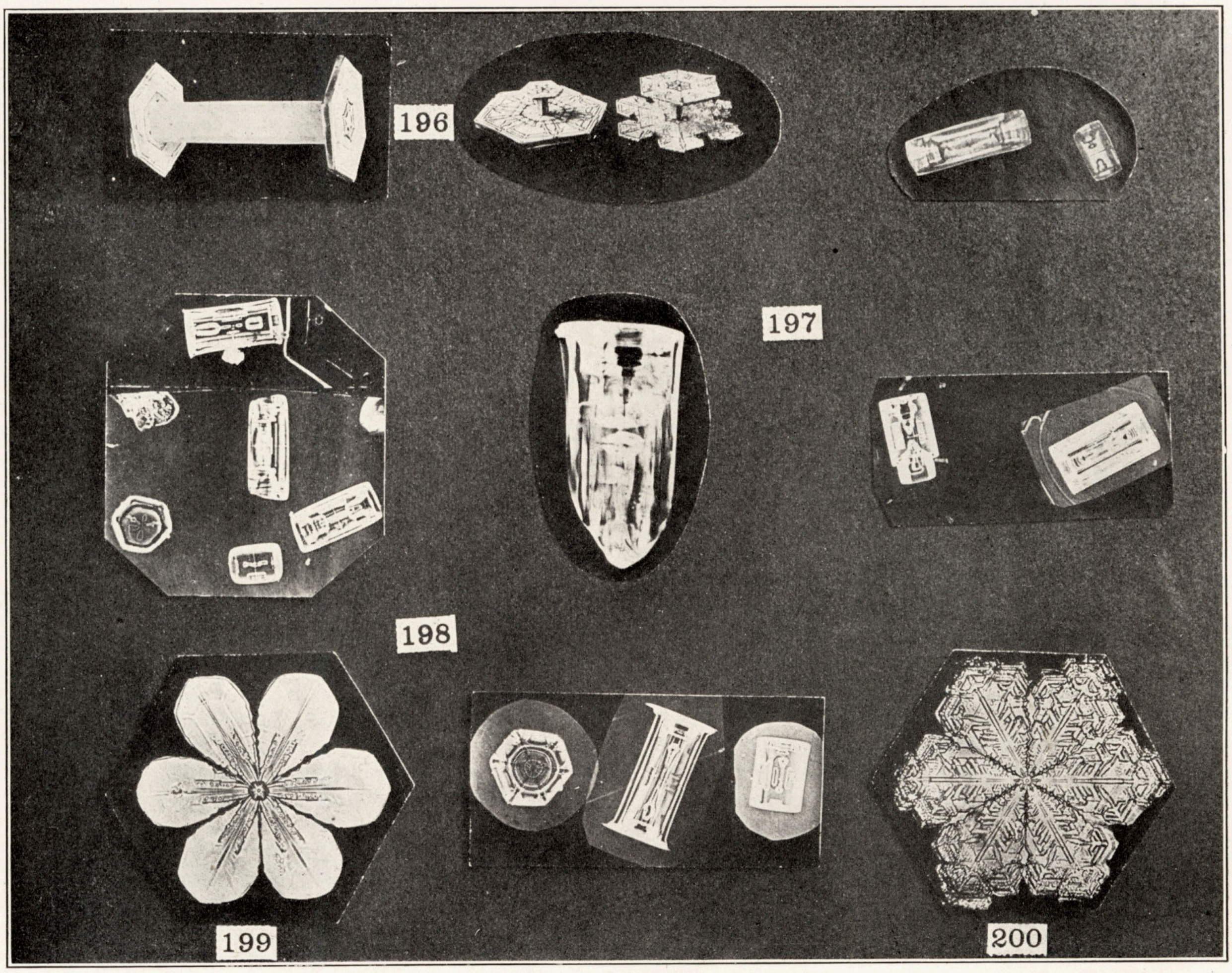

146
147
148
149
150
151
152
153
154
155
156
157


158
159
160
161
162
163


164
165
166
167
168
169
170
171
172


173
174
175
176
177
178
179
180
181
182
183


184
185
186
187
188
189
190
191
192
193
194
195


196
197
198
199
200